PATENT ABSTRACTS OF JAPAN

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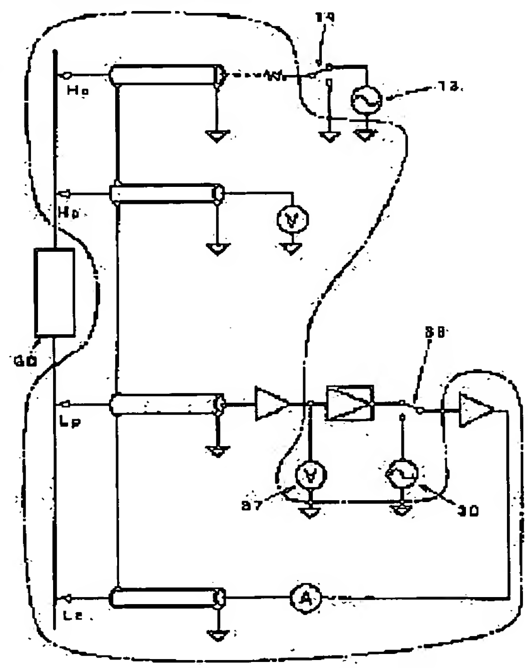
(54) STABILIZATION METHOD FOR FEEDBACK LOOP OF IMPEDANCE MEASURING APPARATUS

(57)Abstract:
PROBLEM TO BE SOLVED: To obtain a stabilization method in which an optimum phase-shift amount can be decided safely over the whole region of an impedance measuring range by a method wherein, when a measuring system is constructed, three known impedances are connected sequentially and the phase characteristic of a feedback loop is measured.
SOLUTION: For example, a first measurement-standard is connected to a measuring terminal, a switch 36 is changed over to the side of an injection power supply, and a null loop is opened. In addition, a switch 14 is changed over to the side of a ground, the transmission characteristic of the null loop is measured, and a first transmission characteristic is obtained. Then, the switch 36 and the switch 14 are returned to their original positions, and a variable phase shifter at a narrow-band high-gain amplifier is set on the basis of the phase-shift value of the transmission characteristic value in such a way that the total phase-shift amount of the null loop becomes 180° . Then, an impedance is measured so as to calibrate the impedance. In this manner, three arbitrary known impedances are connected sequentially, and the one-round phase characteristic of the null loop is measured three times. Thereby, a one- round phase characteristic with reference to an arbitrary impedance to be measured is grasped completely, and an optimum phase compensation amount is computed over the whole range of a measuring value.



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CLAIMS

[Claim(s)]
[Claim 1] A means to impress measurement voltage to the 1st terminal of the measuring object Good change partner stage which absorbs the current which flows for the 2nd terminal of the aforementioned measuring object, has the feedback loop which controls the potential of the 2nd terminal of the above to grounding potential mostly while measuring the current which flows to the measuring object, and was prepared in the measurement means of the transfer characteristics of the aforementioned feedback loop, and this feedback loop It is the feedback-loop stabilization method of impedance measurement equipment equipped with the above, and it is characterized from the transfer characteristics which carried out [aforementioned] measurement by to set up the aforementioned adjustable phase shifter in quest of the amount of optimal phase shifts of the aforementioned adjustable phase shifter by the operation so that two or more known impedances may be connected to a sense terminal one by one, the transfer characteristics of the aforementioned feedback loop may be measured and the stability of the aforementioned feedback loop may be maintained in the whole region of the impedance range of the measuring object which may be connected to the aforementioned sense terminal.
[Claim 2] The feedback-loop stabilization method according to claim 1 characterized by making the number of the aforementioned known impedances into three pieces.
[Claim 3] The feedback-loop stabilization method according to claim 1 characterized by connecting the standard for proofreading to a sense terminal, and performing sequentially measurement for proofreading, and measurement of the transfer characteristics of the aforementioned feedback loop.
[Claim 4] The feedback-loop stabilization method according to claim 1 characterized by making into the amount of optimal phase shifts the amount of phase shifts to which the minimum value of the phase margin by the side of the delay of the aforementioned feedback loop when changing a measurement impedance over the impedance range whole region of the aforementioned measuring object and the minimum value of the phase margin of the advancing side become equal.

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DETAILED DESCRIPTION

[Detailed Description of the Invention]
[0001]
[Industrial Application] this invention relates the property of part constants, such as an impedance, a circuit constant, and material to the impedance measurement equipment which uses the arbitrary measurement cables of especially a long picture, and measures them over the latus impedance range by the RF.
[0002]
[Description of the Prior Art] In low frequency, 4 terminal-pair impedance measurement method is a measuring method which is not influenced of the measurement cable which connects between measuring device main parts with the measuring object. For example, accurate measurement is possible when the measurement cable of preparing a multiplexer between the measuring object and a measuring device main part, and building a system which switches the measuring object and a measuring device main part is long. For this reason, 4 terminal-pair impedance measurement method has spread widely.
[0003] However, if a test frequency becomes high, the accuracy of measurement will fall for transition of the phase in a measurement cable, or the stability of the feedback loop which constitutes the measuring device further will become bad. For this reason, severe restrictions are needed for a measurement cable, and the freedom of cable selection is lost. Moreover, severe conditions are needed also for the aforementioned feedback loop. This detail is given below.
[0004] The circuitry of typical 4 terminal-pair impedance measurement equipment is shown in drawing 2 , and the problem of RF-izing and long-picture-izing of a measurement cable, arbitrary-izing, and a feedback loop is stated to it. In addition, in drawing of the impedance measurement equipment shown drawing 2 and henceforth, the operation control section which controls operations, such as measured value, and the function of a measuring device is omitted.
[0005] In drawing 2 , the measurement current of the source 13 of a measurement signal is supplied to one terminal 61 of the measuring object 60 from the Hc sense terminal 10 via resistance 12 and the measurement cable 11. Measurement current flows from another terminal 62 of the measuring object 60 to the Lc sense terminal 40, flows to the range resistance 43 for current detection via the measurement cable 41, and is drawn in the null amplification means 35. A voltmeter 44 measures the voltage of the ends of resistance 43, and current value is calculated. That is, resistance 43 and the voltmeter 44 constitute the amperometry means 42.
[0006] On the other hand, the potential of the terminal 62 of the measuring object 60 is impressed to the null amplification means 35 through the measurement cable 31 from the Lp sense terminal 30. The output of the null amplification means 35 draws the current of an ammeter 42, and makes potential of the terminal 62 of the measuring object equal to the grounding potential of the null amplification means 35. That is, the feedback loop which consists of the measurement cable 31, the null amplification means 35, the amperometry means 42, the measurement cable 41, and the terminal 62 of the measuring object carries out a negative feedback control, and maintains the potential of the terminal 62 of the measuring object at zero potential. For this reason, on these specifications, this feedback loop will be called nulling loop.
[0007] The potential of the terminal 61 of the measuring object 60 is measured with a voltmeter 22 through the measurement cable 21 from the Hp sense terminal 20. Since the potential of a terminal 62 is kept above to grounding potential, a voltmeter 22 will measure the voltage impressed to the ends of the measuring object 60. Therefore, a desired impedance measurement value can be calculated from the ratio of the measured value of a voltmeter 22, and the measured value of the amperometry means 42.

[0008] If the phase margin of the open loop transfer function of a nulling loop is not enough, a nulling loop will become unstable, and will be oscillated further and 4 terminal-pair measuring circuit will lapse into an unusable state. For this reason, phase compensation is used for the nulling loop. The method of the following [phase compensation / of a nulling loop / former] is enforced.
[0009] As shown in drawing 2 , the null amplification means 35 consists of cascade connection of the input amplifier 32, the narrow-band high interest profit amplifier 33, and an output amplifier 34. The narrow-band high interest profit amplifier 33 is the composition shown in drawing 3 , and the operation is as follows. A synchronizing signal is directly impressed to a wave detector 71 as a criteria phasing signal from the source 79 of a synchronizing signal of the same frequency as the source of a measurement signal, and a phase shift is carried out 90 degrees with a phase shifter 80, and it is impressed by the wave detector 72 as a criteria phasing signal. Therefore, wave detectors 71 and 72 constitute the rectangular synchronous detector.
[0010] The alternating current signals impressed to the input terminal 70 are a wave detector 71 and a wave detector 72, and the synchronous detection of them is divided and carried out to rectangular cross 2 component, and they turn into a direct current signal. Through the adjustable phase shifter 81, the synchronizing signal from the source 79 of a synchronizing signal is impressed to a modulator 75 as a subcarrier, and the phase shift of it is carried out 90 degrees with a phase shifter 82, and it is impressed to the modulator 76. Therefore, modulators 75 and 76 constitute the quadrature modulation machine. After integrating an integrator 73 and an integrator 74 with the aforementioned direct current signal, respectively, it is inputted into a modulator 75 and a modulator 76, is changed into the alternating current signal which has phase contrast 90 degrees mutually, it is further compounded with an adder 77, is restored as an alternating current signal, and it is outputted from an output 78.
[0011] Thus, since the narrow-band high interest profit amplifier 33 carried out the rectangular synchronous detection of the alternating current signal, it changed, integrated with and carried out quadrature modulation to the direct current signal and it is returned to the alternating current signal, high interest profit is realizable by the narrow-band. A phase characteristic in case the gain property and the amount of phase shifts of a phase shifter are zero becomes like drawing 4 . Here, if the phase between a

rectangular wave detector and a quadrature modulation machine is shifted with the adjustable phase shifter 81, narrow-band high interest profit amplifier with arbitrary phase contrast is realizable. The example of phase nature when making phase contrast of this rectangular wave detector and a quadrature modulation machine into 0 times, +90 degrees, and -90 degrees was shown in drawing 5 .

[0012] It is a stability condition to make it 0 times of a phase not exist in the gain band width product of a nulling-loop round including the narrow-band high interest profit amplifier 33. Therefore, if service conditions, such as electric length of a service condition, i.e., a measurement cable, are fixed strictly beforehand, the amount of phase shifts of the narrow-band high interest profit amplifier 33 is adjusted, and it can make before manufacture shipment so that a nulling loop may be stabilized. Or if the function to find the required amount of phase shifts of phase compensation, i.e., the amount, at the time of use is built in impedance measurement equipment, very flexible correspondence will be attained to cable sheath length.

[0013] As a latter means, these people proposed "the Japanese-Patent-Application-No. 01-184223 adaptation type half bridge and the impedance meter." After it separates the source of a measurement signal from a measuring circuit, cuts a nulling loop and measures the amount of phase shifts of the portion except the narrow-band high interest profit amplifier 33 of a nulling loop using an addition circuit, it sets up the adjustable phase shifter 81 so that the total amount of phase shifts of a nulling loop may become 180 degrees.

[0014] Drawing 6 is the principle view. A switch 14 is switched to the earth side and the source 13 of a signal is separated from a measuring circuit. A switch 36 is switched to the source 38 side of a pouring signal, a nulling loop is cut, and pouring signal Ephi is impressed to an output amplifier 34 from the source 38 of a pouring signal. Voltage Vphi which appeared in the outgoing end of the input amplifier 32 in this state is measured by the vector voltmeter 37. The phase contrast of Vphi to pouring signal Ephi is the amount of phase shifts of the nulling loop except the narrow-band high interest profit amplifier 33. From this amount of phase shifts, the adjustable phase shifter 81 is set up so that the total amount of phase shifts of a nulling loop may become 180 degrees.

[0015] Actual phase measurement can be performed by constituting the narrow-band high interest profit amplifier 33 like drawing 7 , and incorporating a phase measuring circuit. In drawing 7 , the integrator consists of an operational amplifier 86, resistance 85, and a capacitor 84. If it connects between I/O of an operational amplifier 86 and the series connection of resistance 83 and a switch 91 furthermore closes an interlock switch 91, an integrator will change to amplifier. The same is said of an operational amplifier 90, resistance 89, a capacitor 88, resistance 87, and an interlock switch 91.

[0016] At the time of phase measurement, the amount of phase shifts of the adjustable phase shifter 81 is set as zero or a known value. Moreover, with a switch 95, the input of a modulator 76 is connected to grounding and the input of a modulator 75 is connected to DC power supply 94. The direct current voltage of DC power supply 94 is changed into an alternating current signal, and is applied to wave detectors 71 and 72 via a buffer 96 from an input 70 involving a nulling loop. A switch 91 is closed and an integrator is switched to a voltage amplifier, and if the direct current voltage divided into the quadrature component with the wave detector 71 and the wave detector 72 is measured by change ******** 93 with a switch 92, it can ask for a phase as the angle of deviation on a Gauss-Argand plane. These are stated to aforementioned Japanese Patent Application No. 01-184223.

[0017] The stages of performing phase measurement of the aforementioned application for patent in all the process of impedance measurement are two either of the degrees.

(1) When the measuring object is connected and impedance measurement orders, assign the first half of each time measurement to the amount determination of phase compensation of a nulling loop.

(2) Determine the amount of phase compensation of a nulling loop in the state of measuring object opening at the time of system constructions, such as cable sheath length, store this in equipment memory, and pull out and use the amount of compensation memorized at the time of measurement of an impedance.

[0018] I hear that a nulling-loop round phase is not the arithmetic sum of the effect which each of a cable-sheath-length portion and a measuring object impedance value does, and important one has it here. That is, it will not be materialized if it is not under a special condition even if it is going to divide and have the function of the change of a phase to the impedance value of the measuring object, and the function of a cable-sheath-length portion.

[0019] The above (1) and (2) have the opposite advantage demerit. If (1) is chosen, although very flexible stabilization can be attained to a measuring object value and cable sheath length, the time of phase measurement is added to the degree of measurement, and it is disadvantageous for improvement in the speed of measurement. If (2) is chosen, although the overhead of the measuring time will not be generated, the guarantee of the nulling-loop stability to arbitrary measuring object values is not obtained. Since the transfer function of a nulling loop changes with the values of the measuring object, it is necessary to obtain the amount of optimal phase compensation which can secure a phase margin from the phase contrast acquired by a certain measuring object over the measuring-range whole region made into an object. For this reason, it cannot but carry out predicting based on the internal configuration of impedance measurement equipment, and by carrying out the limited specialization of the extension of a measurement cable, and flexibility is lost.

[0020]

[Problem(s) to be Solved by the Invention] A means to calculate the amount of optimal phase compensation to arbitrary long measurement cables is built in equipment, if it has the automatic regulation function wide opened to the user, the limit imposed on an extension is removed and flexible impedance measurement equipment can be realized about telemetering. Although it is realized by the Japanese-Patent-Application-No. 01-184223 adaptation type half bridge and the impedance meter, as the preceding clause described, flexible stabilization of a nulling loop and improvement in the speed of measurement are contrary. The technical problem which this invention tends to solve is calculating the most generous amount of stabilization phase compensation correctly through the whole measuring object value range without sacrificing the measuring time.

[0021]

[Means for Solving the Problem] This proposal offers a means to search for the transfer function of a nulling loop with three arbitrary known impedances. To finding out the proper amount of phase corrections, where a certain specific measuring object is connected, by connecting three arbitrary known in PIDA one by one, and measuring a round phase characteristic of a nulling loop 3 times, this invention grasps completely a round property over an arbitrary measuring object impedance, and computes the optimal amount of phase compensation for the whole target measuring object value range in Japanese Patent Application No. 01-184223. According to this method, foresight information, extension assumption, etc. about a internal structure become unnecessary, and all indeterminacy is eliminated.

[0022]

[Example] The flow of explanation is described before explaining this invention in full detail. First, a nulling-loop open-loop transfer function is a function of the impedance Zx of the measuring object, and shows what is described like later (4) formulas. Next, a transfer function is influenced [what] with a measuring object value, or the property is shown roughly, and a phase compensation method is shown. Next, the constant in (4) formulas shows what it can opt for by measuring three known impedances. Finally, the procedure which measures three known impedances is described.
[0023] Although the measuring method of circuitry required to measure round transfer characteristics and round transfer characteristics is the same as that of what is shown in the aforementioned application for patent, next, operation of drawing 6 is outlined by way of precaution.
(1) Separate the source 13 of a signal from a measuring circuit with a switch 14, and a switch 36 cuts a nulling loop. (2) Pour signal Ephi of the same frequency as the source 13 of a measurement signal into a nulling loop from the source 38 of a pouring signal, and measure voltage Vphi of the outgoing end of the input amplifier 32 to this by the vector voltmeter 37. Thereby, round transfer characteristics of the nulling loop except the narrow-band high interest profit amplifier 33 are known.
[0024] Based on drawing 6 , the action which measures the transfer characteristics of a nulling-loop round except the narrow-band high interest profit amplifier 33 including the measuring object is considered. The enclosure of a dashed line as shown in the impedance measurement equipment of drawing 6 at drawing 8 is given. This enclosure can be simplified in a circle of the dashed line of drawing 9 . In addition, a circuit presupposes that it is alignment as an appropriate assumption. It turns out that Vphi makes Jp and Jq a multiplier by ** of superposition, and it is given by the arithmetic sum of the measuring object voltage Vx and Ephi. Namely, [0025]
Vphi=Jp-Vx+Jq-Ephi (1)
[0026] On the other hand, the sense-terminal voltage Eo when opening a sense terminal wide makes Jo a multiplier, and is [0027].
Eo=Jo-Ephi (2)
[0028] When setting to Zo the impedance which peeped into the network through the sense terminal, the voltage Vx at the time of measuring object connection is [0029] from a Thevenin's theorem.
Vx=Zx-Eo/(Zx+Zo) (3)
[0030] Since it is come out and given, (2) is substituted for (3) and (3) is substituted for (1), and it is [0031]. Vphi=Jp-Zx-Jo-Ephi/(Zx+Zo) +Jq-Ephi [0032] Therefore, a transfer function will be [0033] if Kq [Kp and Jq] is newly written for Jp-Jo.
G=V phi/E phi=Kp-Zx / (Zx+Zo) +Kq (4)
[0034] It becomes. It is the constant as which a transfer function G is characterized by three constants Kp, Kq, and Zo among this formula. Here, ** into which the transfer function (4) formula of a nulling loop turns strangely how to Zx is described.
[0035] (4) The feature of a formula is collected by Zx/(Zx+Zo). In the Gauss-Argand plane, the relation with Zx and Zx/(Zx+Zo) was shown in drawing 10 . Positive, then the right half plane field (field of the slash of drawing 10) of Zx are projected on the interior of the circle of drawing 10 with the function of Zx/(Zx+Zo) in the real part of the impedance Zo peeped into through the measuring object as appropriate conditions. The imaginary axis of Zx is the boundary of this circle. The right half plane of Zx is taken up here because negative resistance measuring object measurement is very rare.
[0036] The nulling-loop open-loop transfer function except (4) formulas including Kp and Kq, i.e., narrow-band high interest profit amplifier, projects the right half plane of Zx in the circle of drawing 11 . Since the phase characteristic of narrow-band high interest profit amplifier changes in **90 degrees within a narrow-band, a nulling-loop round phase including narrow-band high interest profit amplifier serves as a field which spreads by a unit of 90 degrees on both sides of a circle like drawing 11 . In the example of drawing 11 , since this field includes the nullity shaft of a Gauss-Argand plane, it may oscillate.
[0037] Then, if the phase of a quadrature modulation machine is advanced only 180-phia degree to a rectangular wave detector, the phase of a nulling loop will serve as a field shown in drawing 12 , and, also at the lowest, phase-margin phim and phin will be secured over the whole region of the measuring object impedance located in the right half plane of Zx. However, phia is the phase angle of the center of a circle. As mentioned above, it is the optimal example of this invention which was adapted for the example of drawing 10 and drawing 11 to ask for phia, to add amount of phase shifts 180-phia degree, and to attain stabilization of a nulling loop.
[0038] Next, how to ask for the constants Kp, Kq, and Zo of (4) formulas is described. (4) Transform a formula and it is [0039].
A=Kp+Kq B=Kq-Zo C=Zo (5)
[0040] The following formula will be obtained if it replaces.
[0041]
Zx-A+B-G-C=G-Zx (6)
[0042] A, B, and C are made clear by measuring the transfer characteristics of a nulling loop to the measuring object of three known impedances. They are G1, G2, G3, then simultaneous equations [0043] in a known impedance about the measured value of the transfer characteristics of Z1, Z2, Z3, and a nulling loop.
[Equation 1]

$$\begin{bmatrix} Z1 & 1 & -G1 \\ Z2 & 1 & -G2 \\ Z3 & 1 & -G3 \end{bmatrix} \begin{bmatrix} A \\ B \\ C \end{bmatrix} = \begin{bmatrix} G1 \cdot Z1 \\ G2 \cdot Z2 \\ G3 \cdot Z3 \end{bmatrix} \qquad (7)$$

[0044] **********. A, B, and C are [0045] from this.
[Equation 2]

$$\begin{bmatrix} A \\ B \\ C \end{bmatrix} = \begin{bmatrix} Z1 & 1 & -G1 \\ Z2 & 1 & -G2 \\ Z3 & 1 & -G3 \end{bmatrix}^{-1} \begin{bmatrix} G1 \cdot Z1 \\ G2 \cdot Z2 \\ G3 \cdot Z3 \end{bmatrix} \qquad (8)$$

[0046] It becomes. phia is known if Kp, Kq, and Zo are obtained from a formula (8) and (5). By the way, when the system which extended the cable is usually built, proofreading of the system by three impedance standards known in the name of OPEN,

SHORT, and LOAD is performed. The three above-mentioned impedance standard can be used also [measurement / transfer-characteristics / of the nulling loop to three impedances of this invention]. this invention can be performed to either before and after impedance proofreading, and the unknown of the nulling-loop transfer function of this invention can be determined.
[0047] The flow chart when carrying out this invention to drawing 1 at the time of system constructions, such as cable sheath length, is shown. The 1st standard is connected to a sense terminal at Step 2. At Step 3, the switch 36 of drawing 6 is switched to a pouring power supply side, and a nulling loop is opened. Moreover, a switch 14 is switched to the earth side. At Step 4, the transfer characteristics of a nulling loop are measured and the 1st transfer-characteristics value G1 is acquired. The adjustable phase shifter of narrow-band high interest profit amplifier is set up so that a switch 36 and a switch 14 may be returned and the total amount of phase shifts of a nulling loop may become 180 degrees based on the phase shift value of the above G1 at Step 5.

[0048] At Step 5, since the stability of a nulling loop was secured, it is Step 6 and performs impedance measurement for impedance proofreading.
[0049] Next, it progresses to a phase 11. The phase 11 is omitted drawing, although it consists of the same steps as the phase 10 measured by the 1st standard. After setting up the adjustable phase shifter of narrow-band high interest profit amplifier so that may connect the 2nd standard by the phase 11, Step 3 to the same step 69 as a phase 10 may be operated, and the 2nd transfer-characteristics value G2 may be acquired and the total amount of phase shifts of a nulling loop may become 180 degrees based on the phase shift value of G2, impedance measurement of the 2nd standard is performed for impedance proofreading. Similarly, by the phase 12, 3rd transfer-characteristics value G3 is obtained and impedance measurement of the 3rd standard is performed. At Step 13, Kp, Kq, and Zo are calculated using a formula (8) and (5) as mentioned above, and a formula (4) is obtained from the three above-mentioned transfer function measured value. The impedance range of the measuring object is substituted for Zx of a formula (4), phia is obtained, and the optimal amount of phase shifts is calculated. The calculated amount of phase shifts is set up at Step 14.
[0050] In the above-mentioned procedure, the phase compensation of a nulling loop does not affect the impedance measurement value for proofreading, as long as it is a thing for stabilization of the negative feedback circuit and the nulling loop is operating stably. Therefore, a proofreading result is not affected even if it sets the amount of phase shifts obtained in the above-mentioned procedure as an adjustable phase shifter. In addition, no solution of the amount of phase compensation which attains the conditions of nulling-loop stability to an object and the total measuring object value to plan exists, and there may be. It is also possible to emit warning and to urge an improvement of a cable-sheath-length portion also in that case, at the time of phase compensation functional execution, if required.
[0051] In addition, only phase compensation was described so far. In this description, phase compensation is used for a wide sense and adjustment of gain compensation is also possible for it by the same method according to a case. Practically, it is required to prepare the means of gain adjustment in somewhere in narrow-band high interest profit amplifier or nulling-loop rounds. Although the example of this invention was shown above, it does not limit to the format of instantiation, and arrangement and others, and change of composition is also permitted, without losing the main point of this invention if needed.
[0052]
[Effect of the Invention] When telemetering was performed by the RF, the flexible solution was proposed about the phase compensation problem of feedback amplifier (nulling loop) indispensable to 4 terminal-pair impedance measurement equipment. A nulling-loop round property over arbitrary measuring object impedances can be completely presumed now by connecting and measuring three known impedances to a sense terminal. And the amount of phase compensation can be collectively acquired now in the case of impedance proofreading of the system by OPEN/SHORT/LOAD. According to this method, through all the ranges of the measuring object impedance made into the measuring object, one assumption cannot be found, either, the safe amount of phase compensation can be determined mechanically, and, moreover, the overhead of measuring object speed is not generated. And it presents [it is not necessary to limit a service condition, make the high-speed impedance measurement equipment which meets flexibly the demand of high-frequency measurement etc. whose diversification of cable length and the quality of the material, use of a multiplexer, and wavelength exceed cable length realize, and] practical use and is useful.

[Translation done.]

TECHNICAL FIELD

[Industrial Application] this invention relates the property of part constants, such as an impedance, a circuit constant, and material to the impedance measurement equipment which uses the arbitrary measurement cables of especially a long picture, and measures them over the latus impedance range by the RF.

[Translation done.]

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PRIOR ART

[Description of the Prior Art] In low frequency, 4 terminal-pair impedance measurement method is a measuring method which is not influenced of the measurement cable which connects between measuring device main parts with the measuring object. For example, accurate measurement is possible when the measurement cable of preparing a multiplexer between the measuring object and a measuring device main part, and building a system which switches the measuring object and a measuring device main part is long. For this reason, 4 terminal-pair impedance measurement method has spread widely.
[0003] However, if a test frequency becomes high, the accuracy of measurement will fall for transition of the phase in a measurement cable, or the stability of the feedback loop which constitutes the measuring device further will become bad. For this reason, severe restrictions are needed for a measurement cable, and the freedom of cable selection is lost. Moreover, severe conditions are needed also for the aforementioned feedback loop. This detail is given below.
[0004] The circuitry of typical 4 terminal-pair impedance measurement equipment is shown in drawing 2 , and the problem of RF-izing and long-picture-izing of a measurement cable, arbitrary-izing, and a feedback loop is stated to it. In addition, in drawing of the impedance measurement equipment shown drawing 2 and henceforth, the operation control section which controls operations, such as measured value, and the function of a measuring device is omitted.
[0005] In drawing 2 , the measurement current of the source 13 of a measurement signal is supplied to one terminal 61 of the measuring object 60 from the Hc sense terminal 10 via resistance 12 and the measurement cable 11. Measurement current flows from another terminal 62 of the measuring object 60 to the Lc sense terminal 40, flows to the range resistance 43 for current detection via the measurement cable 41, and is drawn in the null amplification means 35. A voltmeter 44 measures the voltage of the ends of resistance 43, and current value is calculated. That is, resistance 43 and the voltmeter 44 constitute the amperometry means 42.
[0006] On the other hand, the potential of the terminal 62 of the measuring object 60 is impressed to the null amplification means 35 through the measurement cable 31 from the Lp sense terminal 30. The output of the null amplification means 35 draws the current of an ammeter 42, and makes potential of the terminal 62 of the measuring object equal to the grounding potential of the null amplification means 35. That is, the feedback loop which consists of the measurement cable 31, the null amplification means 35, the amperometry means 42, the measurement cable 41, and the terminal 62 of the measuring object carries out a negative feedback control, and maintains the potential of the terminal 62 of the measuring object at zero potential. For this reason, on these specifications, this feedback loop will be called nulling loop.
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[0008] If the phase margin of the open loop transfer function of a nulling loop is not enough, a nulling loop will become unstable, and will be oscillated further and 4 terminal-pair measuring circuit will lapse into an unusable state. For this reason, phase compensation is used for the nulling loop. The method of the following [phase compensation / of a nulling loop / former] is enforced.
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[0010] The alternating current signals impressed to the input terminal 70 are a wave detector 71 and a wave detector 72, and the synchronous detection of them is divided and carried out to rectangular cross 2 component, and they turn into a direct current signal. Through the adjustable phase shifter 81, the synchronizing signal from the source 79 of a synchronizing signal is impressed to a modulator 75 as a subcarrier, and the phase shift of it is carried out 90 degrees with a phase shifter 82, and it is impressed to the modulator 76. Therefore, modulators 75 and 76 constitute the quadrature modulation machine. After integrating an integrator 73 and an integrator 74 with the aforementioned direct current signal, respectively, it is inputted into a modulator 75 and a modulator 76, is changed into the alternating current signal which has phase contrast 90 degrees mutually, it is further compounded with an adder 77, is restored as an alternating current signal, and it is outputted from an output 78.
[0011] Thus, since the narrow-band high interest profit amplifier 33 carried out the rectangular synchronous detection of the alternating current signal, it changed, integrated with and carried out quadrature modulation to the direct current signal and it is returned to the alternating current signal, high interest profit is realizable by the narrow-band. A phase characteristic in case the gain property and the amount of phase shifts of a phase shifter are zero becomes like drawing 4 . Here, if the phase between a rectangular wave detector and a quadrature modulation machine is shifted with the adjustable phase shifter 81, narrow-band high interest profit amplifier with arbitrary phase contrast is realizable. The example of phase nature when making phase contrast of this rectangular wave detector and a quadrature modulation machine into 0 times, +90 degrees, and -90 degrees was shown in drawing 5 .
[0012] It is a stability condition to make it 0 times of a phase not exist in the gain band width product of a nulling-loop round including the narrow-band high interest profit amplifier 33. Therefore, if service conditions, such as electric length of a service

condition, i.e., a measurement cable, are fixed strictly beforehand, the amount of phase shifts of the narrow-band high interest profit amplifier 33 is adjusted, and it can make before manufacture shipment so that a nulling loop may be stabilized. Or if the function to find the required amount of phase shifts of phase compensation, i.e., the amount, at the time of use is built in impedance measurement equipment, very flexible correspondence will be attained to cable sheath length.

[0013] As a latter means, these people proposed "the Japanese-Patent-Application-No. 01-184223 adaptation type half bridge and the impedance meter." After it separates the source of a measurement signal from a measuring circuit, cuts a nulling loop and measures the amount of phase shifts of the portion except the narrow-band high interest profit amplifier 33 of a nulling loop using an addition circuit, it sets up the adjustable phase shifter 81 so that the total amount of phase shifts of a nulling loop may become 180 degrees.

[0014] Drawing 6 is the principle view. A switch 14 is switched to the earth side and the source 13 of a signal is separated from a measuring circuit. A switch 36 is switched to the source 38 side of a pouring signal, a nulling loop is cut, and pouring signal Ephi is impressed to an output amplifier 34 from the source 38 of a pouring signal. Voltage Vphi which appeared in the outgoing end of the input amplifier 32 in this state is measured by the vector voltmeter 37. The phase contrast of Vphi to pouring signal Ephi is the amount of phase shifts of the nulling loop except the narrow-band high interest profit amplifier 33. From this amount of phase shifts, the adjustable phase shifter 81 is set up so that the total amount of phase shifts of a nulling loop may become 180 degrees.

[0015] Actual phase measurement can be performed by constituting the narrow-band high interest profit amplifier 33 like drawing 7, and incorporating a phase measuring circuit. In drawing 7, the integrator consists of an operational amplifier 86, resistance 85, and a capacitor 84. If it connects between I/O of an operational amplifier 86 and the series connection of resistance 83 and a switch 91 furthermore closes an interlock switch 91, an integrator will change to amplifier. The same is said of an operational amplifier 90, resistance 89, a capacitor 88, resistance 87, and an interlock switch 91.

[0016] At the time of phase measurement, the amount of phase shifts of the adjustable phase shifter 81 is set as zero or a known value. Moreover, with a switch 95, the input of a modulator 76 is connected to grounding and the input of a modulator 75 is connected to DC power supply 94. The direct current voltage of DC power supply 94 is changed into an alternating current signal, and is applied to wave detectors 71 and 72 via a buffer 96 from an input 70 involving a nulling loop. A switch 91 is closed and an integrator is switched to a voltage amplifier, and if the direct current voltage divided into the quadrature component with the wave detector 71 and the wave detector 72 is measured by change ******** 93 with a switch 92, it can ask for a phase as the angle of deviation on a Gauss-Argand plane. These are stated to aforementioned Japanese Patent Application No. 01-184223.

[0017] The stages of performing phase measurement of the aforementioned application for patent in all the process of impedance measurement are two either of the degrees.

(1) When the measuring object is connected and impedance measurement orders, assign the first half of each time measurement to the amount determination of phase compensation of a nulling loop.

(2) Determine the amount of phase compensation of a nulling loop in the state of measuring object opening at the time of system constructions, such as cable sheath length, store this in equipment memory, and pull out and use the amount of compensation memorized at the time of measurement of an impedance.

[0018] I hear that a nulling-loop round phase is not the arithmetic sum of the effect which each of a cable-sheath-length portion and a measuring object impedance value does, and important one has it here. That is, it will not be materialized if it is not under a special condition even if it is going to divide and have the function of the change of a phase to the impedance value of the measuring object, and the function of a cable-sheath-length portion.

[0019] The above (1) and (2) have the opposite advantage demerit. If (1) is chosen, although very flexible stabilization can be attained to a measuring object value and cable sheath length, the time of phase measurement is added to the degree of measurement, and it is disadvantageous for improvement in the speed of measurement. If (2) is chosen, although the overhead of the measuring time will not be generated, the guarantee of the nulling-loop stability to arbitrary measuring object values is not obtained. Since the transfer function of a nulling loop changes with the values of the measuring object, it is necessary to obtain the amount of optimal phase compensation which can secure a phase margin from the phase contrast acquired by a certain measuring object over the measuring-range whole region made into an object. For this reason, it cannot but carry out predicting based on the internal configuration of impedance measurement equipment, and by carrying out the limited specialization of the extension of a measurement cable, and flexibility is lost.

[Translation done.]

EFFECT OF THE INVENTION

[Effect of the Invention] When telemetering was performed by the RF, the flexible solution was proposed about the phase compensation problem of feedback amplifier (nulling loop) indispensable to 4 terminal-pair impedance measurement equipment. A nulling-loop round property over arbitrary measuring object impedances can be completely presumed now by connecting and measuring three known impedances to a sense terminal. And the amount of phase compensation can be collectively acquired now in the case of impedance proofreading of the system by OPEN/SHORT/LOAD. According to this method, through all the ranges of the measuring object impedance made into the measuring object, one assumption cannot be found, either, the safe amount of phase compensation can be determined mechanically, and, moreover, the overhead of measuring object speed is not generated. And it presents [it is not necessary to limit a service condition, make the high-speed impedance measurement equipment which meets flexibly the demand of high-frequency measurement etc. whose diversification of cable length and the quality of the material, use of a multiplexer, and wavelength exceed cable length realize, and] practical use and is useful.

[Translation done.]

TECHNICAL PROBLEM

[Problem(s) to be Solved by the Invention] A means to calculate the amount of optimal phase compensation to arbitrary long measurement cables is built in equipment, if it has the automatic regulation function wide opened to the user, the limit imposed on an extension is removed and flexible impedance measurement equipment can be realized about telemetering. Although it is realized by the Japanese-Patent-Application-No. 01-184223 adaptation type half bridge and the impedance meter, as the preceding clause described, flexible stabilization of a nulling loop and improvement in the speed of measurement are contrary. The technical problem which this invention tends to solve is calculating the most generous amount of stabilization phase compensation correctly through the whole measuring object value range without sacrificing the measuring time.

[Translation done.]

MEANS

[Means for Solving the Problem] This proposal offers a means to search for the transfer function of a nulling loop with three arbitrary known impedances. To finding out the proper amount of phase corrections, where a certain specific measuring object is connected, by connecting three arbitrary known in PIDA one by one, and measuring a round phase characteristic of a nulling loop 3 times, this invention grasps completely a round property over an arbitrary measuring object impedance, and computes the optimal amount of phase compensation for the whole target measuring object value range in Japanese Patent Application No. 01-184223. According to this method, foresight information, extension assumption, etc. about a internal structure become unnecessary, and all indeterminacy is eliminated.

[Translation done.]

EXAMPLE

[Example] The flow of explanation is described before explaining this invention in full detail. First, a nulling-loop open-loop transfer function is a function of the impedance Zx of the measuring object, and shows what is described like later (4) formulas. Next, a transfer function is influenced [what] with a measuring object value, or the property is shown roughly, and a phase compensation method is shown. Next, the constant in (4) formulas shows what it can opt for by measuring three known impedances. Finally, the procedure which measures three known impedances is described.
[0023] Although the measuring method of circuitry required to measure round transfer characteristics and round transfer characteristics is the same as that of what is shown in the aforementioned application for patent, next, operation of drawing 6 is outlined by way of precaution.
(1) Separate the source 13 of a signal from a measuring circuit with a switch 14, and a switch 36 cuts a nulling loop. (2) Pour signal Ephi of the same frequency as the source 13 of a measurement signal into a nulling loop from the source 38 of a pouring signal, and measure voltage Vphi of the outgoing end of the input amplifier 32 to this by the vector voltmeter 37. Thereby, round transfer characteristics of the nulling loop except the narrow-band high interest profit amplifier 33 are known.
[0024] Based on drawing 6 , the action which measures the transfer characteristics of a nulling-loop round except the narrow-band high interest profit amplifier 33 including the measuring object is considered. The enclosure of a dashed line as shown in the impedance measurement equipment of drawing 6 at drawing 8 is given. This enclosure can be simplified in a circle of the dashed line of drawing 9 . In addition, a circuit presupposes that it is alignment as an appropriate assumption. It turns out that Vphi makes Jp and Jq a multiplier by ** of superposition, and it is given by the arithmetic sum of the measuring object voltage Vx and Ephi. Namely, [0025]
Vphi=Jp-Vx+Jq-Ephi (1)
[0026] On the other hand, the sense-terminal voltage Eo when opening a sense terminal wide makes Jo a multiplier, and is [0027].
Eo=Jo-Ephi (2)
[0028] When setting to Zo the impedance which peeped into the network through the sense terminal, the voltage Vx at the time of measuring object connection is [0029] from a Thevenin's theorem.
Vx=Zx-Eo/(Zx+Zo) (3)
[0030] Since it is come out and given, (2) is substituted for (3) and (3) is substituted for (1), and it is [0031]. Vphi=Jp-Zx-Jo-Ephi/(Zx+Zo) +Jq-Ephi [0032] Therefore, a transfer function will be [0033] if Kq [Kp and Jq] is newly written for Jp-Jo.
G=V phi/E phi=Kp-Zx / (Zx+Zo) +Kq (4)
[0034] It becomes. It is the constant as which a transfer function G is characterized by three constants Kp, Kq, and Zo among this formula. Here, ** into which the transfer function (4) formula of a nulling loop turns strangely how to Zx is described.
[0035] (4) The feature of a formula is collected by Zx/(Zx+Zo). In the Gauss-Argand plane, the relation with Zx and Zx/(Zx+Zo) was shown in drawing 10 . Positive, then the right half plane field (field of the slash of drawing 10) of Zx are projected on the interior of the circle of drawing 10 with the function of Zx/(Zx+Zo) in the real part of the impedance Zo peeped into through the measuring object as appropriate conditions. The imaginary axis of Zx is the boundary of this circle. The right half plane of Zx is taken up here because negative resistance measuring object measurement is very rare.
[0036] The nulling-loop open-loop transfer function except (4) formulas including Kp and Kq, i.e., narrow-band high interest profit amplifier, projects the right half plane of Zx in the circle of drawing 11 . Since the phase characteristic of narrow-band high interest profit amplifier changes in **90 degrees within a narrow-band, a nulling-loop round phase including narrow-band high interest profit amplifier serves as a field which spreads by a unit of 90 degrees on both sides of a circle like drawing 11 . In the example of drawing 11 , since this field includes the nullity shaft of a Gauss-Argand plane, it may oscillate.
[0037] Then, if the phase of a quadrature modulation machine is advanced only 180-phia degree to a rectangular wave detector, the phase of a nulling loop will serve as a field shown in drawing 12 , and, also at the lowest, phase-margin phim and phin will be secured over the whole region of the measuring object impedance located in the right half plane of Zx. However, phia is the phase angle of the center of a circle. As mentioned above, it is the optimal example of this invention which was adapted for the example of drawing 10 and drawing 11 to ask for phia, to add amount of phase shifts 180-phia degree, and to attain stabilization of a nulling loop.
[0038] Next, how to ask for the constants Kp, Kq, and Zo of (4) formulas is described. (4) Transform a formula and it is [0039].
A=Kp+Kq B=Kq-Zo C=Zo (5)
[0040] The following formula will be obtained if it replaces.
[0041]
Zx-A+B-G-C=G-Zx (6)
[0042] A, B, and C are made clear by measuring the transfer characteristics of a nulling loop to the measuring object of three known impedances. They are G1, G2, G3, then simultaneous equations [0043] in a known impedance about the measured value of the transfer characteristics of Z1, Z2, Z3, and a nulling loop.
[Equation 1]

$$\begin{bmatrix} Z1 & 1 & -G1 \\ Z2 & 1 & -G2 \\ Z3 & 1 & -G3 \end{bmatrix} \begin{bmatrix} A \\ B \\ C \end{bmatrix} = \begin{bmatrix} G1 \cdot Z1 \\ G2 \cdot Z2 \\ G3 \cdot Z3 \end{bmatrix} \quad (7)$$

[0044] **********. A, B, and C are [0045] from this.
[Equation 2]

$$\begin{bmatrix} A \\ B \\ C \end{bmatrix} = \begin{bmatrix} Z1 & 1 & -G1 \\ Z2 & 1 & -G2 \\ Z3 & 1 & -G3 \end{bmatrix}^{-1} \begin{bmatrix} G1 \cdot Z1 \\ G2 \cdot Z2 \\ G3 \cdot Z3 \end{bmatrix} \quad (8)$$

[0046] It becomes. phia is known if Kp, Kq, and Zo are obtained from a formula (8) and (5). By the way, when the system which extended the cable is usually built, proofreading of the system by three impedance standards known in the name of OPEN, SHORT, and LOAD is performed. The three above-mentioned impedance standard can be used also [measurement / transfer-characteristics / of the nulling loop to three impedances of this invention]. this invention can be performed to either before and after impedance proofreading, and the unknown of the nulling-loop transfer function of this invention can be determined.
[0047] The flow chart when carrying out this invention to drawing 1 at the time of system constructions, such as cable sheath length, is shown. The 1st standard is connected to a sense terminal at Step 2. At Step 3, the switch 36 of drawing 6 is switched to a pouring power supply side, and a nulling loop is opened. Moreover, a switch 14 is switched to the earth side. At Step 4, the transfer characteristics of a nulling loop are measured and the 1st transfer-characteristics value G1 is acquired. The adjustable phase shifter of narrow-band high interest profit amplifier is set up so that a switch 36 and a switch 14 may be returned and the total amount of phase shifts of a nulling loop may become 180 degrees based on the phase shift value of the above G1 at Step 5.

[0048] At Step 5, since the stability of a nulling loop was secured, it is Step 6 and performs impedance measurement for impedance proofreading.
[0049] Next, it progresses to a phase 11. The phase 11 is omitted drawing, although it consists of the same steps as the phase 10 measured by the 1st standard. After setting up the adjustable phase shifter of narrow-band high interest profit amplifier so that may connect the 2nd standard by the phase 11, Step 3 to the same step 69 as a phase 10 may be operated, and the 2nd transfer-characteristics value G2 may be acquired and the total amount of phase shifts of a nulling loop may become 180 degrees based on the phase shift value of G2, impedance measurement of the 2nd standard is performed for impedance proofreading. Similarly, by the phase 12, 3rd transfer-characteristics value G3 is obtained and impedance measurement of the 3rd standard is performed. At Step 13, Kp, Kq, and Zo are calculated using a formula (8) and (5) as mentioned above, and a formula (4) is obtained from the three above-mentioned transfer function measured value. The impedance range of the measuring object is substituted for Zx of a formula (4), phia is obtained, and the optimal amount of phase shifts is calculated. The calculated amount of phase shifts is set up at Step 14.
[0050] In the above-mentioned procedure, the phase compensation of a nulling loop does not affect the impedance measurement value for proofreading, as long as it is a thing for stabilization of the negative feedback circuit and the nulling loop is operating stably. Therefore, a proofreading result is not affected even if it sets the amount of phase shifts obtained in the above-mentioned procedure as an adjustable phase shifter. In addition, no solution of the amount of phase compensation which attains the conditions of nulling-loop stability to an object and the total measuring object value to plan exists, and there may be. It is also possible to emit warning and to urge an improvement of a cable-sheath-length portion also in that case, at the time of phase compensation functional execution, if required.
[0051] In addition, only phase compensation was described so far. In this description, phase compensation is used for a wide sense and adjustment of gain compensation is also possible for it by the same method according to a case. Practically, it is required to prepare the means of gain adjustment in somewhere in narrow-band high interest profit amplifier or nulling-loop rounds. Although the example of this invention was shown above, it does not limit to the format of instantiation, and arrangement and others, and change of composition is also permitted, without losing the main point of this invention if needed.

[Translation done.]

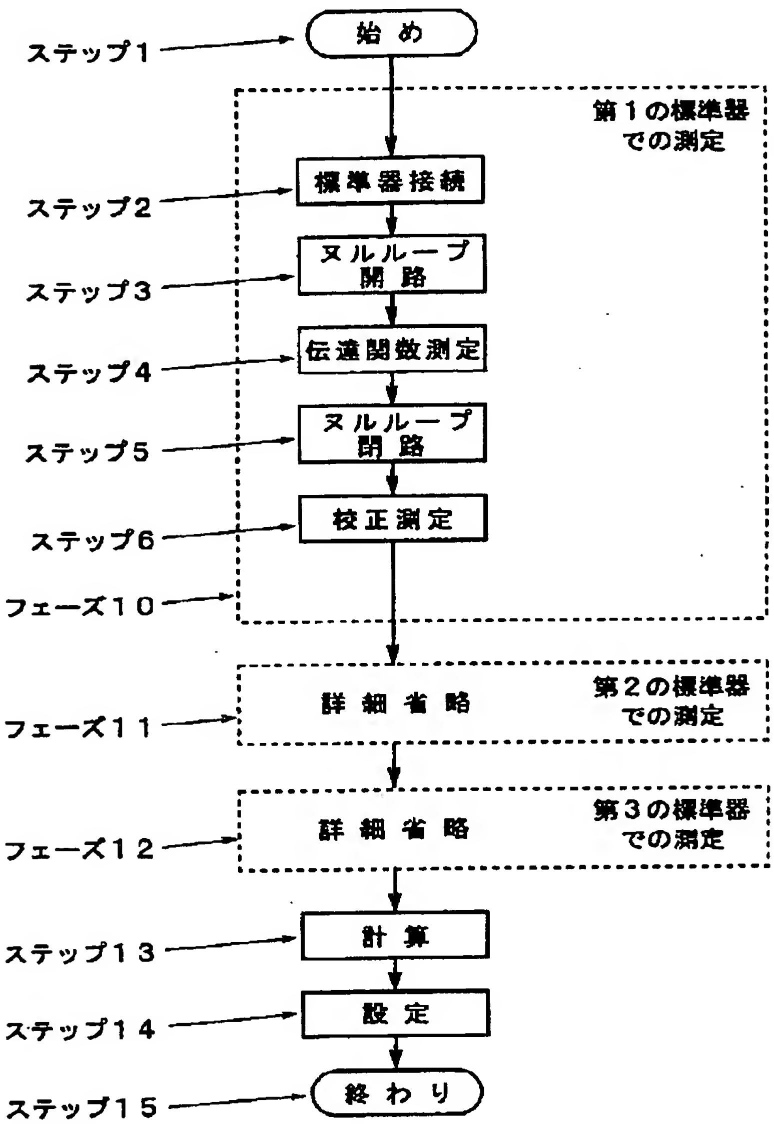
DESCRIPTION OF DRAWINGS

[Brief Description of the Drawings]
[Drawing 1] It is drawing showing the example of this invention.
[Drawing 2] It is drawing showing the example of 4 terminal-pair impedance measurement equipment of the conventional technology.
[Drawing 3] It is drawing showing the example of a narrow band amplifier.
[Drawing 4] It is drawing showing the example of the frequency characteristic of a narrow band amplifier.
[Drawing 5] It is drawing showing the example of the phase-shift property of a narrow band amplifier.
[Drawing 6] It is drawing showing the example of the conventional technology.
[Drawing 7] It is drawing showing the example of the conventional technology.
[Drawing 8] It is drawing showing the range of a nulling-loop round measurement equal circuit.
[Drawing 9] It is drawing showing the example of a nulling-loop round measurement equal circuit.
[Drawing 10] It is drawing showing the example of projection Zx/(Zx+Zo).
[Drawing 11] It is drawing showing the example of projection Kp-Zx/(Zx+Zo)+Kq.
[Drawing 12] It is drawing showing the example of the projection after a phase shift.
[Description of Notations]
10: Hc sense terminal
11: Measurement cable
12: Resistance
13: The source of a signal
14: Switch
20: Hp sense terminal
21: Measurement cable
22: Voltmeter
30: Lp sense terminal
31: Measurement cable
32: Input amplifier
33: Narrow-band high interest profit amplifier
34: Output amplifier
35: Null amplifier
36: Switch
37: Vector voltmeter
38: The source of a pouring signal
40: Lc sense terminal
41: Measurement cable
42: Ammeter
43: Range resistance
44: Voltmeter
60: Measuring object
61: The terminal of the measuring object
62: The terminal of the measuring object
70: Narrow-band high interest profit amplifier input
71: Synchronous detector
72: Synchronous detector
73: Integrator
74: Integrator
75: Modulator
76: Modulator
77: Adder
78: Narrow-band high interest profit amplifier output
79: The source of a synchronizing signal
80:90-degree phase shifter
81: Adjustable phase shifter
82:90-degree phase shifter
83: Resistance
84: Capacitor
85: Resistance
86: Operational amplifier
87: Resistance
88: Capacitor

89: Resistance
90: Operational amplifier
91: Switch
92: Switch
93: Voltmeter
94: Dc source
95: Switch
96: Buffer amplifier

[Translation done.]

Drawing selection drawing 1



[Translation done.]

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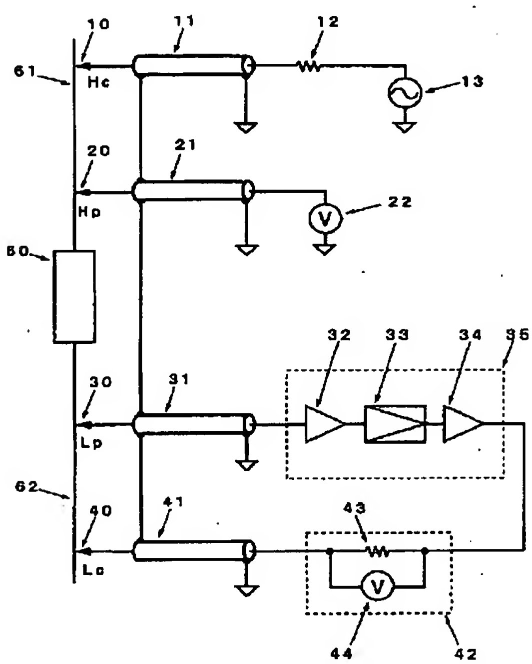

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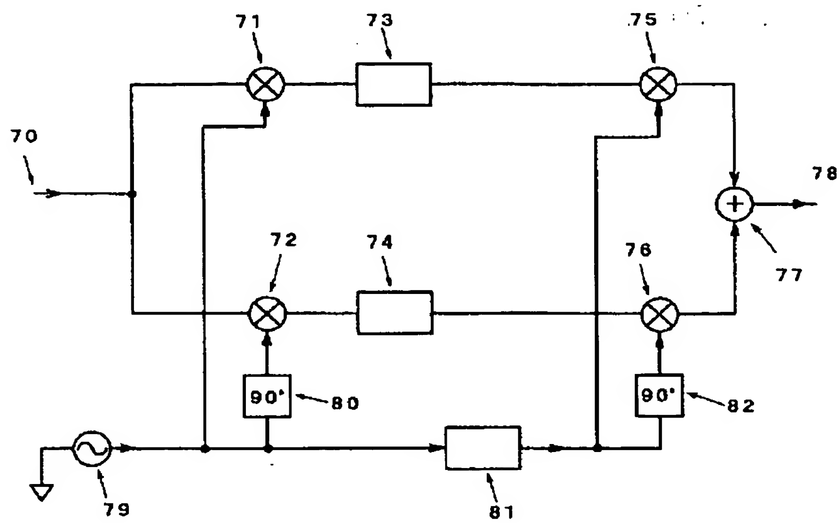

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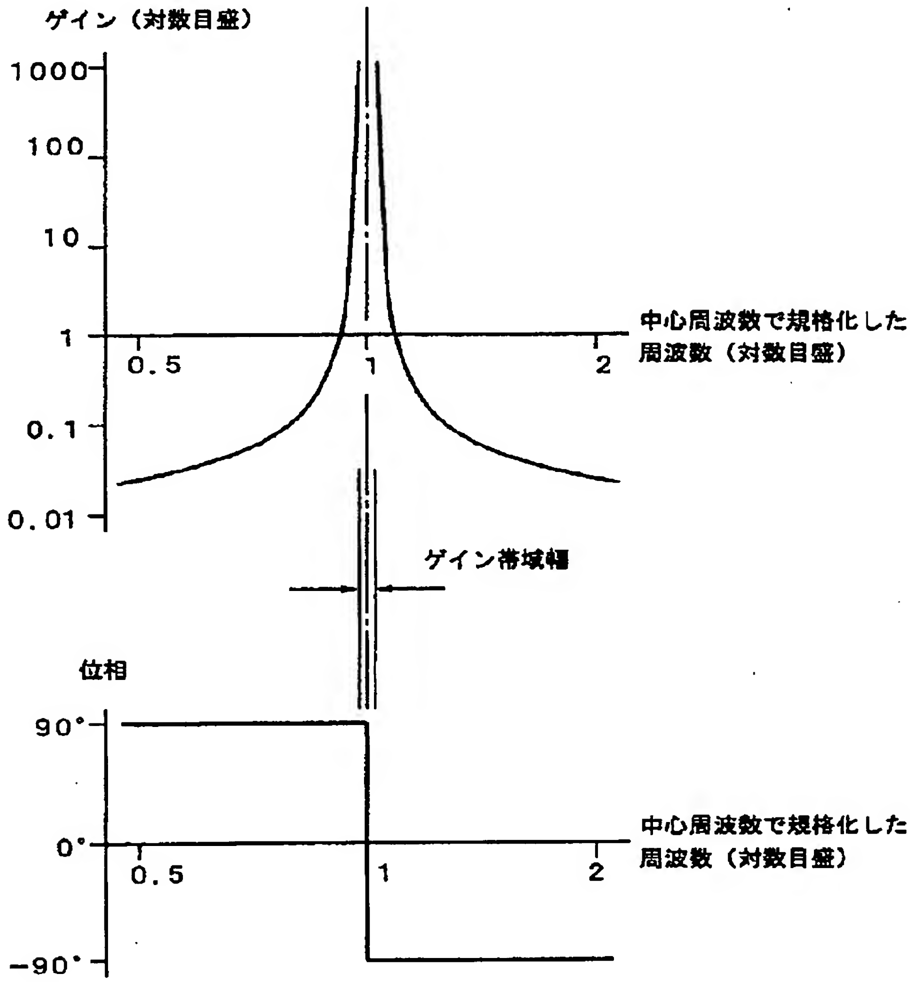

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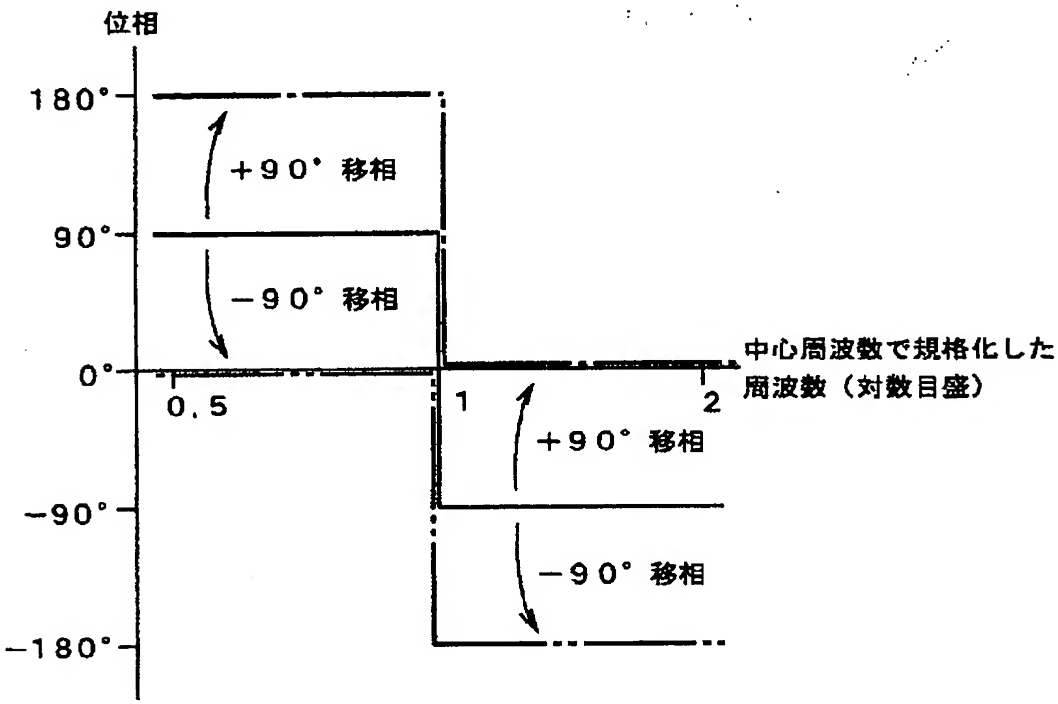

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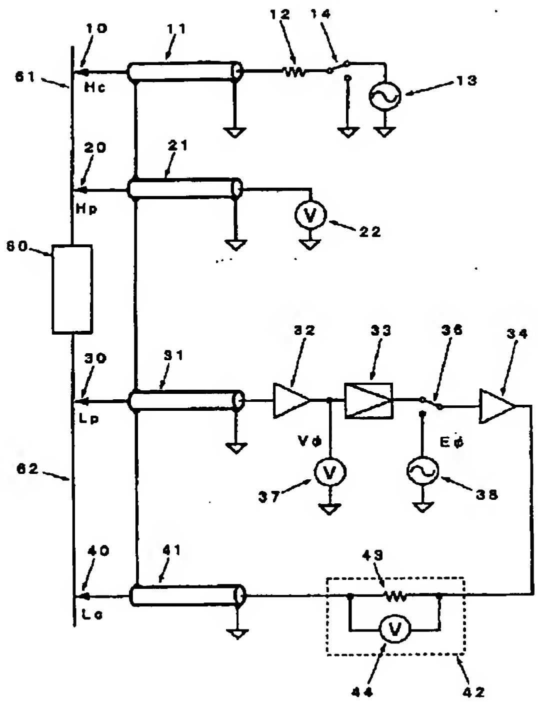

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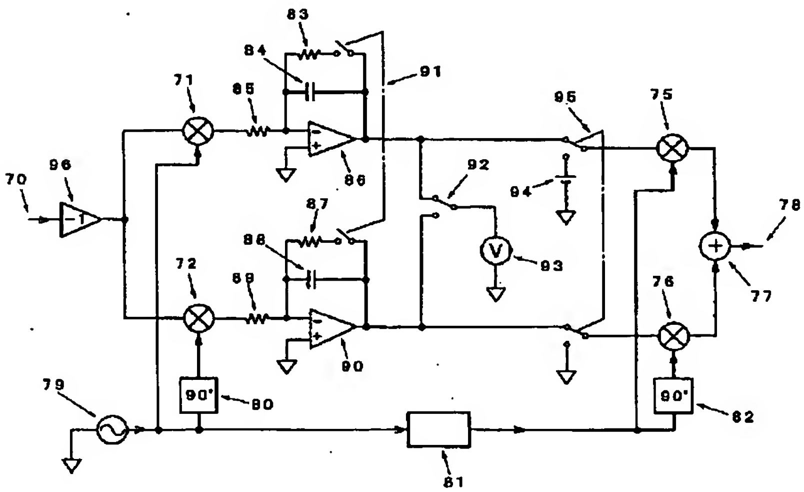
Drawing selection drawing 7



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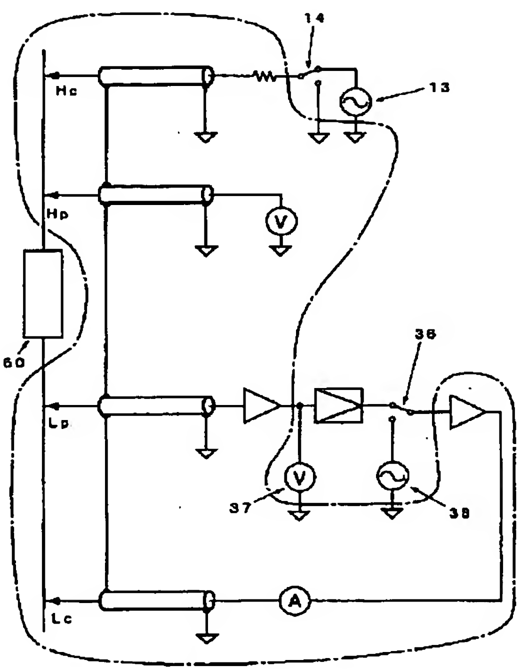

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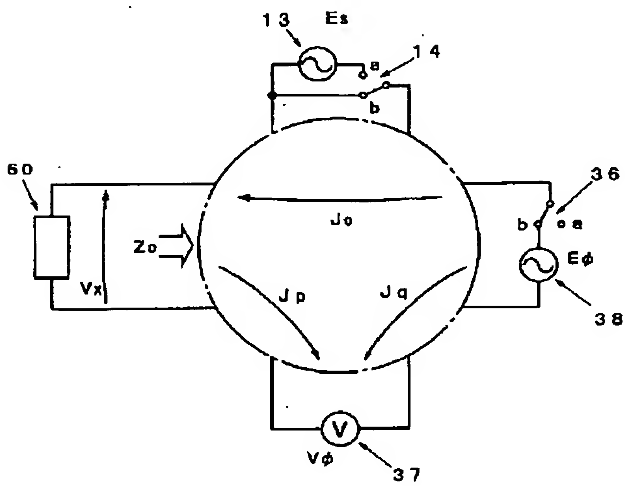

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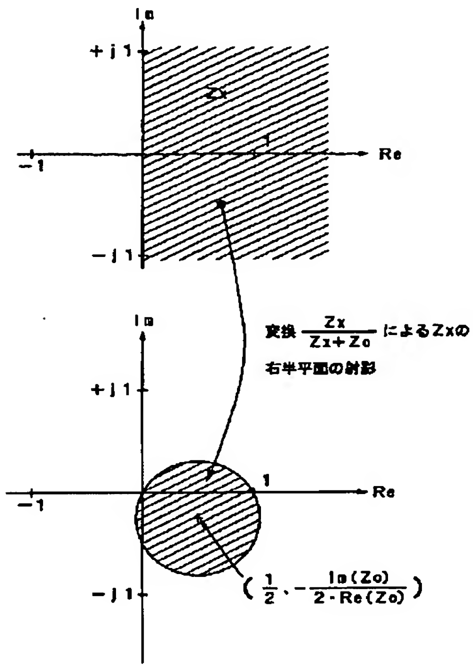
Drawing selection drawing 10



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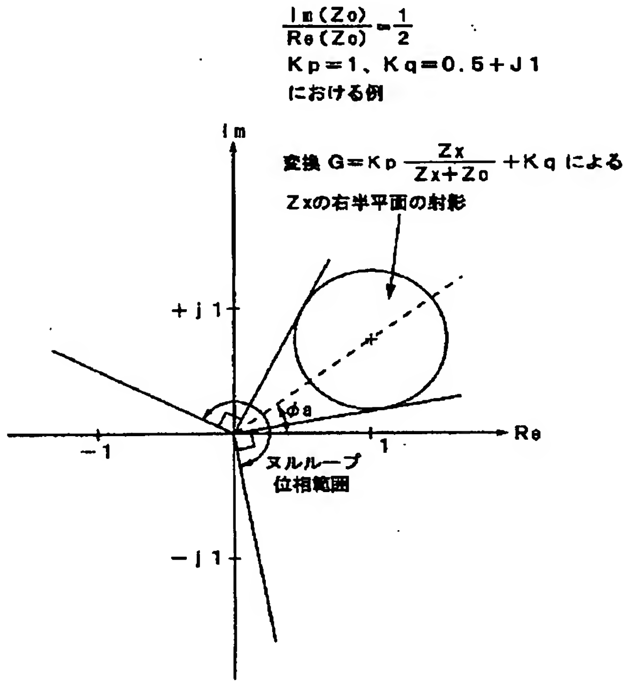
Drawing selection drawing 11



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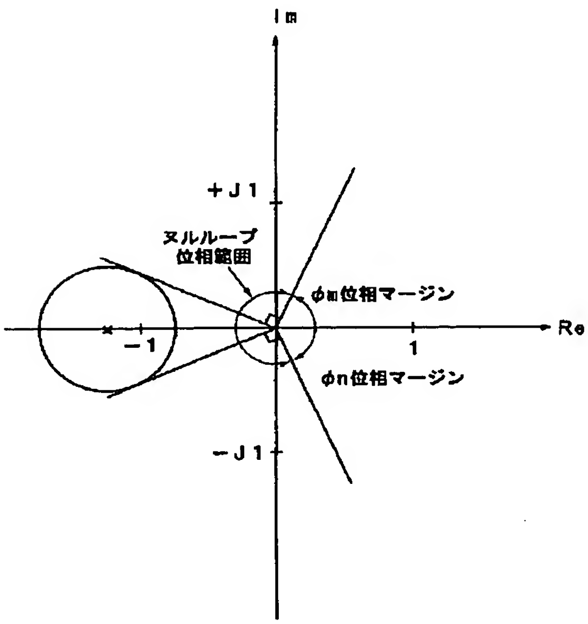
Drawing selection drawing 12



[Translation done.]